

Course Title: Mathematical Optimization Foundations of Data Science

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Course Objectives:

The goal of this course is to enable the students to make informed decision about appropriate machine learning models through better understanding of the underlying optimization techniques, thus improving the performance of the final model. In this class, the students will obtain deep understanding of optimization models employed within machine learning models, and learn their characteristics such as convergence, limitations, and possible extensions.

Course Contents:

The tentative list of topics to be covered in this class are basics of optimization theory, gradient-based optimization, linear regression and its extensions, least-squares classification and logistic regression, Newton methods in machine learning, basics of constrained optimization, Lagrangian relaxation and duality, support vector machines, and optimization in neural networks

Tentative Textbook:

Aggarwal, Charu C. *Linear Algebra and Optimization for Machine Learning: A Textbook*. Berlin: Springer, 2020.

Tentative Course Outline:

- Linear algebra and optimization
- Univariate and multivariate optimization
- Optimization for machine learning with numerical targets, binary targets, and multi-class settings
- Least-square optimization and its application (linear regression and logistic regression)
- Gradient-based Optimization
 - Gradient Descent
 - Stochastic Gradient Descent
 - Adjusting First-Order Derivatives for Descent (AdaGrad, Adam, RMSProp)
- Second-order methods and application in linear regression and logistics regression
- Constrained optimization and duality
- Application of constrained optimization in constrained regression
- Duality for support vector machines
- Optimization in neural networks

Grading Policies:

The final grade in the course will be determined as follows.

- **Homework Assignment: 30%.** Homework assignments are posted through Canvas. Each homework description indicates whether late submission is accepted for that homework or not. If late submission is accepted, it will be subject to some penalty stated in the homework description.
- **Midterm: 35%.**
- **Final: 35%.**
- **Participation: Bonus 2%.** Participation will be highly encouraged, and the students will receive up to 2% bonus points for active participation.